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THE E702A DISPLAY STORAGE TUBE

Report No. T-098

(1962/35)

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

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Section	Title	Page
	SUMMARY	1
1	INTRODUCTION	1
2	DESCRIPTION OF THE TUBE	1
	2.1. Physical Construction	1
	2.2. Mode of Operation	2
3	EXPERIMENTAL WORK DONE ON THE TUBE	3
	3.1. Selection of Operating Conditions	3
	3.1.1. Electron Collimation	3
	3.1.2. Erasure	3
	3.1.3. Peak Brightness of the Display	4
	3.1.4. Residual Images after Erasure	5
	3.2. Performance of the Tube	8
4	CONCLUSIONS	10
5	REFERENCES	10

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THE E702A DISPLAY STORAGE TUBE

SUMMARY

Tests have been carried out on an E702A display storage tube in order to assess its potentialities for the display of single television pictures.

1. INTRODUCTION

The English Electric E702A display storage tube, which is similar to the 6866 tube of R.C.A.,[1] provides a continuous visual display of signals that would cause only transient excitation of the phosphor of a conventional cathode-ray tube. In particular the tube can be used to store a single television picture and display it for about half a minute at high brightness with reasonable half-tone rendering; the stored picture can then be erased. A potential application for a tube offering this facility lies in the transmission, over a narrow bandwidth channel, of single pictures selected from a "live" television programme, by means of a slow-speed scanning technique similar to that already used in the Cablefilm[2] system. Display storage tubes have already been used in the U.S. for a device that facilitates editing of video-tape recordings.[3]

2. DESCRIPTION OF THE TUBE

2.1. Physical Construction

The construction of the tube is shown in Fig. 1, together with the manufacturers' recommended values for the various electrode voltages. The tube includes:

(a) A writing gun, electrostatically focused and deflected, to which the information to be displayed is applied.

(b) A storage element consisting of a fine, electro-formed, metallic mesh (the backing electrode) which is coated, on the side facing the gun, with a thin layer of insulating material; this covers the metal but not the holes in the mesh.

(c) A viewing or "flood" gun which causes a collimated beam of electrons to approach the storage element, with uniform velocity and density, over its entire surface.

(d) A viewing screen, located immediately beyond the storage element and held at a high positive potential.

(e) A woven collector mesh which lies close to the storage element on the side nearer the electron guns.

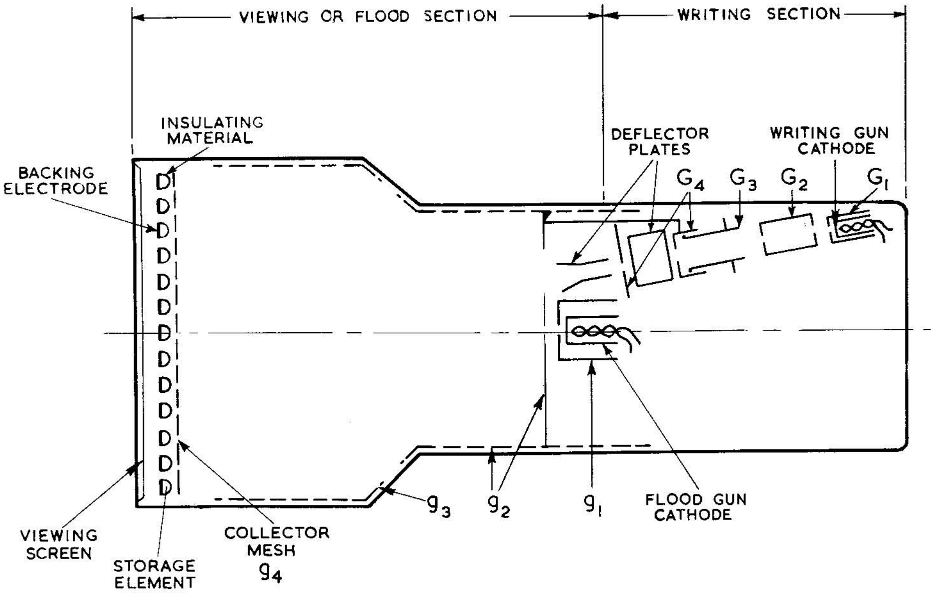

Fig. 1 - Schematic diagram of the E702A storage tube with manufacturers' recommended electro potentials

2.2. Mode of Operation

If we assume the tube to have been switched on for several minutes, with the writing gun cut off and the backing electrode held at its normal potential, the surface of the storage element will be stabilized at a potential near to that of the cathode of the flood gun. In these conditions, electrons approaching the storage element are attracted, through its holes, by the positive potential of the viewing screen, which thus attains a high brightness over its entire area. To prepare the tube for writing, the potential of the backing electrode is first raised by about five volts; the surface potential of the insulated layer rises with it, but falls rapidly owing to the deposition of flood-gun electrons. When the surface potential has almost regained its equilibrium value, the backing electrode is restored to its original potential, thus stabilizing the surface at a potential about five volts below that of the flood-gun cathode. This potential is sufficiently negative to prevent flood-gun electrons from reaching the viewing screen; they therefore return to the collector.

In order to store a single television picture, the writing gun is turned on for one picture period and the storage element is scanned with an electron beam modulated by the video signal. The beam strikes the insulating layer with an energy of about 2·3 keV, resulting in a secondary-emission ratio greater than unity, and the secondary electrons are collected by the collector electrode. Thus, as each part of the insulated surface of the storage element is scanned, it undergoes a positive change of potential, proportional to the instantaneous beam current, and thus permits the passage of flood-gun electrons in direct relation to the corresponding value of the video signal. Those flood-gun electrons that pass through the mesh excite the phosphor, and the picture is reproduced on the viewing screen.

The maximum writing current is restricted to a value such that all points of the storage surface remain below the potential of the flood-gun cathode, and this surface does not collect any of the electrons that it controls. The duration of the display is, in fact, limited only by the presence, between collector and storage element, of positive ions produced by collisions between flood electrons and residual gas molecules. These ions are attracted to the storage surface where they gradually neutralize the negative charge, causing the screen brightness to build up towards its maximum value. To erase the charge pattern on the storage surface, the backing electrode is re-connected to a positive potential for a time sufficient to allow flood-gun electrons to restore the entire storage surface to the potential of the flood-gun cathode. While the erasing pulse is applied the viewing-screen voltage is switched off, in order to prevent electrons from being attracted away from the storage element.

3. EXPERIMENTAL WORK DONE ON THE TUBE

The object of the experimental work carried out on this tube was to determine the best operating conditions for the display of television pictures, and to assess the performance under those conditions.

3.1. Selection of Operating Conditions

3.1.1. Electron Collimation

The potentials of the flood-gun electrodes g_1 and g_3, which control the collimation of the flood electrons and the uniformity of their distribution over the storage element, are adjusted to give the best uniformity of brightness over the largest possible screen area when the storage surface is at a uniform potential. For the specimen tested it was found beneficial to raise the potential of the collector, g_4, from its recommended value of 210 V to 285 V; otherwise the optimum electrode voltages were found to be very similar to those recommended by the manufacturers. The tube tested showed two dark patches within the illuminated screen-area, which could only be restored to an acceptable brightness by adjusting the flood beam to illuminate an area corresponding to rather less than the 4 in (10·2 cm) of useful screen diameter claimed for the tube; the largest raster that could be used for an acceptably uniform display had, in fact, a diagonal of 3·3 in (8·4 cm)

3.1.2. Erasure

The potential of the storage surface, just before writing takes place, is determined by the amplitude and duration of the preceding erase pulse, and must lie within quite narrow limits for satisfactory operation of the tube. The larger the erase pulse, the more negatively biased is the storage surface before the next writing operation takes place, and the higher must be the mean value of the writing current in order to bring the surface potential up to the value required for any given display brightness.

There are, however, small-area non-uniformities in the change of potential produced by a given writing current; thus, for a constant writing current, the surface potential exhibits a degree of non-uniformity proportional to the writing-current. Consequently, if the erase-pulse amplitude is too large, an affect similar to photographic "grain" mars the display.

In order to minimize this grain it would appear desirable for the uniform potential of the storage surface immediately after erasure to lie just below that required to cut off the current to the screen. Unfortunately, poor erasure would then occur in the dark areas of a stored television picture. This is because the writing current would have to be prevented from increasing the potential of the associated areas of the storage surface by more than a small fraction of a volt. At the onset of the next erasing pulse, therefore, these areas would have potentials exceeding the equilibrium value by a correspondingly small amount, and would not be sufficiently positive to achieve effective capture of flood-gun electrons.

It was found that the limits set by these two effects left a latitude of less than one volt in the choice of the storage-surface potential after erasure. However, it did not matter, over quite wide limits, what combination of pulse amplitude and pulse duration was used for attaining the required potential; the same potential could, equally well, be attained for erase-pulse durations ranging from 100 ms to 3 s provided that the erase-pulse amplitude was varied correspondingly between 4·8 V and 4 V. For erasure in less than 100 ms, it was found necessary to employ a lower storage-surface potential at the end of the erase pulse and tolerate a consequent increase in the grain of the display. In these conditions it was possible to reduce the erasure time to a minimum of about 30 ms.

3.1.3. Peak Brightness of the Display

For a screen voltage of 10 kV the peak brightness obtainable from the tube was about 2,000 foot-lamberts, but in order to achieve a degree of resolution at all adequate for the display of television pictures it was found necessary to restrict the peak brightness to about 200 foot-lamberts. As the peak brightness of the display was further restricted the resolution continued to improve slightly, but the picture was then increasingly marred by a background pattern. The pattern is illustrated in Fig. 2, which is a photograph of the display corresponding to a constant writing current.

It will be observed that the displayed pattern, which corresponds to the weave of the collector mesh, is made more objectionable by the presence of a comparatively coarse modulation of its intensity indicating irregularity in the mesh structure. This patterning was more obvious with low brightness than with higher brightness. As the brightness was increased and the resolution of the tube deteriorated, the patterning became defocused, and it virtually disappeared for brightnesses exceeding 700 foot-lamberts.

The resolution obtainable with a given brightness improved as the viewing-screen voltage was increased, and, although the manufacturers recommend 7 kV, the experimental work was carried out at 10 kV. It has since been found that a very slight further improvement in resolution can be achieved by increasing this voltage to its maximum rating of 12 kV.

Fig. 3 shows the control-grid characteristic of the writing gun. The curves plotted refer, respectively, to the cathode current, the total beam current incident on the collector mesh and storage element, and the current drawn by the grid G_2.

Fig. 2 - Display for a constant writing current

Observation of the G_2 current was adopted as a convenient means of monitoring the operation of the writing gun because the grid G_2 was operated at earth potential and its current characteristic closely resembled that of the cathode. It was found that when writing television pictures, using an erase-pulse amplitude adjusted to the optimum value, the current in G_2 did not exceed 10 μA. Thus, the writing gun was operated under conditions very near to cut-off.

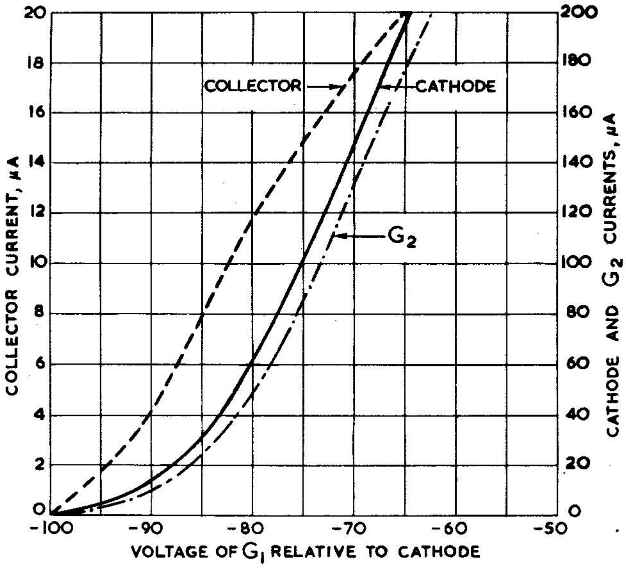

Fig. 3 - Writing-gun characteristics

3.1.4. Residual Images after Erasure

After a number of cycles of writing and erasure have been carried out, using the same picture, a faint negative of that picture appears when, following erasure, positive-ion collection causes the potential of the storage surface to drift above cut-off. The appearance of a residual image after erasure is noted by the manufacturers in the data sheets for the tube, and is stated to be caused by writing-beam electrons penetrating the surface of the storage insulator, thus building up a charge pattern that the relatively low-energy electrons from the flood gun cannot erase. However, this does not explain why no residual image is visible if, immediately after erasure, the surface potential is brought above cut-off by raising the potential of the backing electrode. The remedy recommended by the manufacturers is to discharge the storage element by connecting the backing electrode to the collector for a sufficient time to allow stabilization to occur, and this is found to be effective.

It has further been observed that a negative image appears if, after erasure of a picture that has been written and erased repeatedly, the storage element is scanned at a constant writing current. Fig. 4 shows the display produced in this way after 10 cycles of writing and erasing Test Card "C".

It appears that a given writing current causes least change of potential for those parts of the storage surface that have previously received most electrons from the writing gun. The effect does not seem to have been mentioned in the literature, and an experiment was carried out in order to observe quantitatively the progressive reduction in the change of surface potential brought about by successive

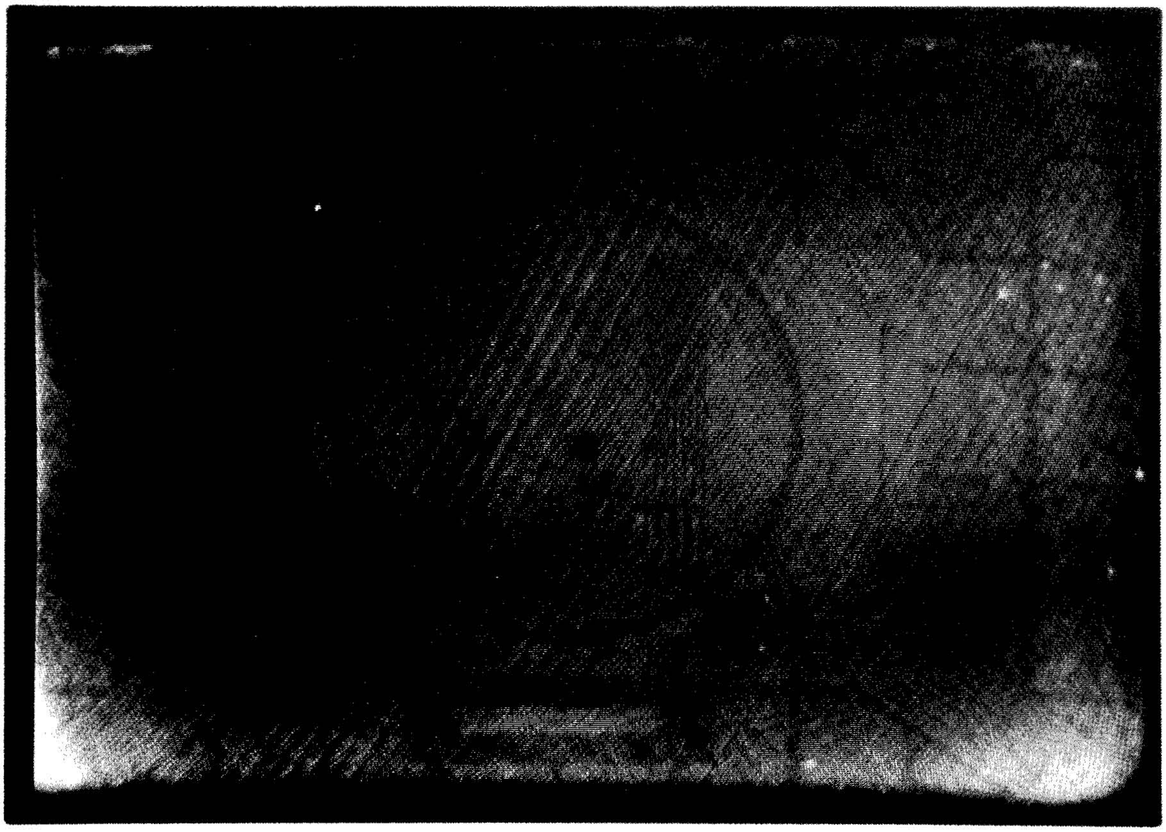

Fig. 4 - Residual image after 10 cycles of writing and erasing Test Card "C"

scans at the same writing current. The storage element was first discharged by connecting the backing electrode to the collector, and the tube was then taken through eighty cycles of writing and erasure. Each writing operation consisted of scanning the storage element at a constant writing current for two field periods; the value of the current was such that, initially, the display brightness was 200 foot-lamberts. The erase pulse had an amplitude of 4 V and a duration of 3 s, and it was observed that throughout the experiment this resulted in a brightness of 0·5 foot-lambert after erasure.

Fig. 5 shows how the brightness resulting from the writing operation varied during the experiment. It will be seen that by the end of the eighty cycles this brightness had declined to one eighth. By measuring the characteristic relating the display brightness to the surface potential, this reduction in brightness was found to correspond to a halving of the change of surface potential caused by the writing current.

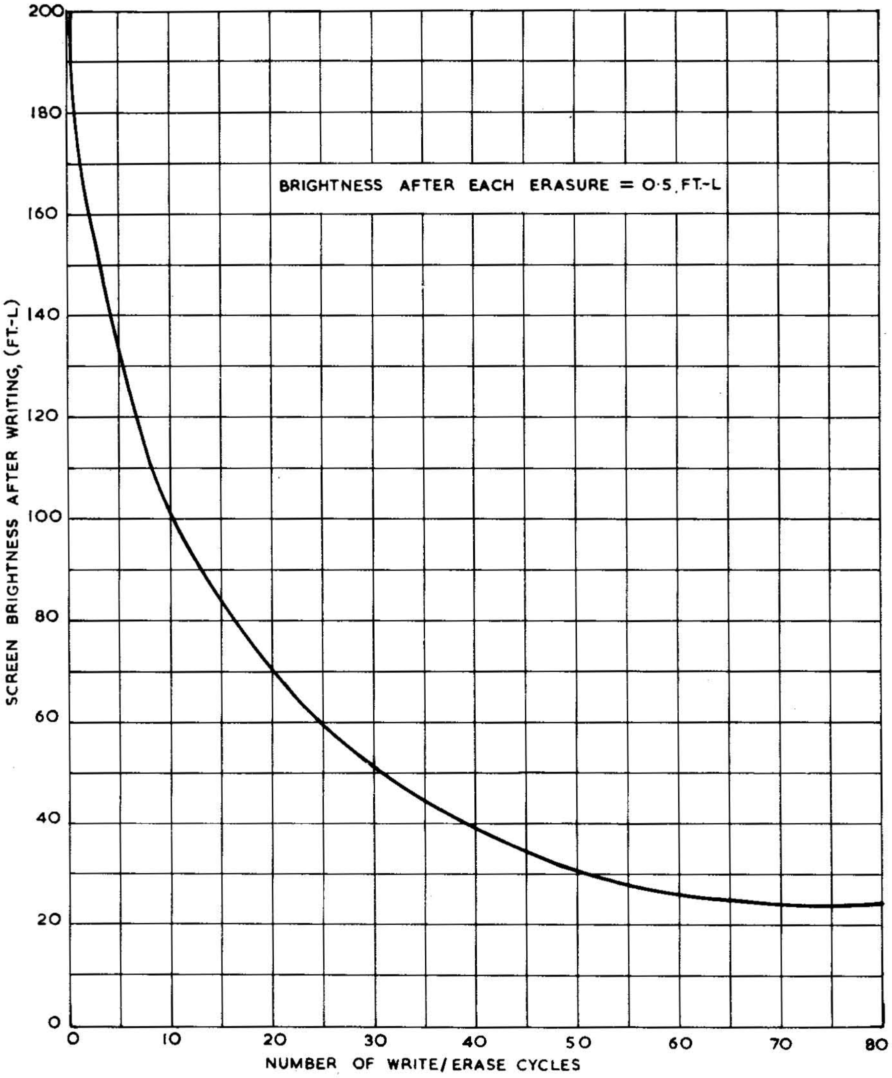

Fig. 5 - The display brightness resulting from the constants value of the writing current

In order to overcome the difficulties resulting from this phenomenon, the backing electrode may be connected to the collector after each writing operation and before applying the normal erase pulse. An alternative procedure was used in the present tests; before using the tube, it was subjected to many cycles of writing and erasure, as just described, and writing was then carried out with the beam current increased in order to compensate for the lower but more constant sensitivity.

3.2. Performance of the Tube

Fig. 6 shows typical displays, photographed from the face of the tube. For these pictures the erasure was arranged to give minimum grain and the brightness and contrast were chosen for the best compromise as regards pattern visibility, resolution, and the avoidance of undue black crushing.

In order to display the resolution of the tube to the best advantage, the picture diagonal was increased to a value about ten per cent above the 3·3 in (8·4 cm) given earlier, and this resulted in the considerable shading apparent in these pictures and also in Figs. 2 and 4. The video signal was pre-emphasized using a derivative equalizer set to give about 8 dB boost at 2 Mc/s by means of the second derivative only.

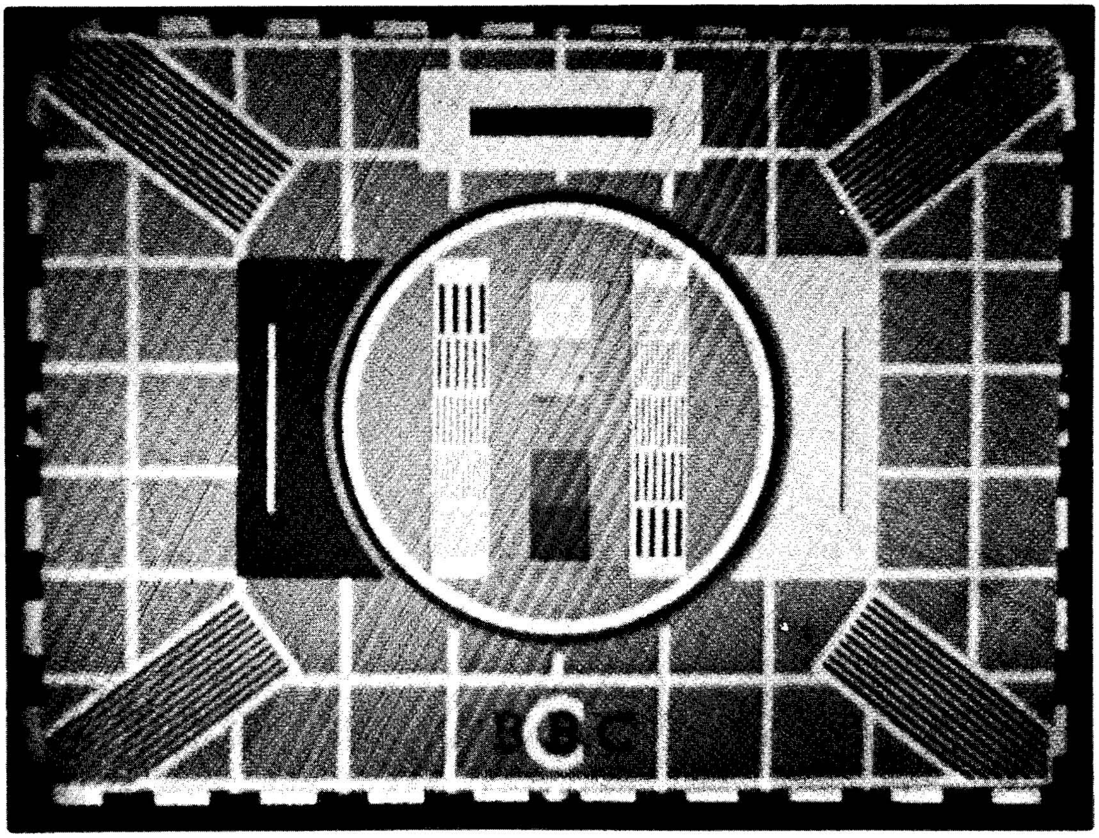

Fig. 6(a) - Photograph of the display obtained with an E702A storage tube

(b)

(c)

Figs. 6(b) and (c) - Photographs of the display obtained with an E702A storage tube

The very small size of the picture tends to conceal some of its shortcomings when the display is viewed directly, and for subjective assessment, a Vidicon camera channel was used in order to allow the picture produced by the tube to be seen on a 21 in (53 cm) monitor. It was felt that the picture quality assessed under these conditions was too poor for any normal programme application and was thought to be inferior to that obtainable from rapidly-processed film recordings.

When the pictures were viewed by means of the Vidicon camera, the drift towards higher brightness, caused by the collection of positive ions, became noticeable after about fifteen seconds, and rendered the picture unusable after about forty seconds. It should be noted that these figures refer to the time for which the picture is actually displayed; provided that the flood beam is cut off, the picture can be stored for many hours.

Apart from the reduction of sensitivity over the first few operations, the tube was found to be stable and easy to operate.

4. CONCLUSIONS

The optimum working conditions for the tube have been found to be similar to those recommended by the manufacturers, although the peak brightness of the display must be restricted to about a tenth of its maximum value in order to maintain even the degree of resolution shown in the photographs. The background pattern superimposed on the displayed picture is a major shortcoming and would obviously become worse if any attempt were made to equalize the overall amplitude/frequency characteristic by applying correction to the signal from a camera viewing the tube face. Since neither of the tube's principal defects can be improved without worsening the other, it is unlikely that the tube would be satisfactory for any television broadcasting application that involved transmission of the displayed picture.

5. REFERENCES

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